The Coherer Detector

Part 1. History and Theory

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Introduction

The coherer was the first practical radio-wave detector. Its most common form was a glass tube containing metallic filings. A coherer exhibits a drop in electrical resistance when acted upon by an electric wave. Early wireless (1896-1906) depended on the coherer for detection of the signals. It was succeeded by more sensitive and reliable detectors such as the electrolyic detector, magnetic detector, the crystal diode, Fleming valve, deForest audion, high-vacuum radio tubes, transistors and integrated circuits.

Early History

James Clerk Maxwell developed the mathematical theory of electromagnetic waves (1863-1873) and showed that their velocity was the same as that of light. About a year before Maxwell died (he died in 1879), David E. Hughes of London, a music professor, while experimenting with a carbon microphone, discovered something remarkable. He had connected in series with a telephone a glass tube filled with filings of zinc and silver. He noticed that a nearby spark discharge caused a change in the electrical resistance of the column of filings. Later, he built a clockwork-keyed spark transmitter and found he could detect a signal at distances up to 500 yards. An associate, Professor Stokes, said it could simply be explained by electromagnetic induction and the matter was soon forgotten.

A few years later (1884), Professor T. Calzecchi-Onesti of Italy also discovered that certain metallic powders showed a decrease in electrical resistance in the presence of strong electrical activity. See Figure 1-A. Again, no one paid any attention.

In 1887, Heinrich Hertz, a professor at the technical college of Karlsruhe, proved the existence of electromagnetic waves by showing that he could generate and detect them. He demonstrated that they followed the same laws of reflection, refraction and polarization as light. All of this is a rather remarkable accomplishment considering that his detector was simply a loop of wire with a miniature spark gap at its open end, see Figure 1-B. Sometimes a piece of black paper was held behind the spark gap so that the spark could more easily be seen.

The First Coherers 1, 2, 3

In 1890, Edouard Branly, a doctor of medicine and a part-time professor of physics at the Catholic University of Paris, after extensive research, produced a working coherer and gave it its most common form - namely a tube filled with metallic filings loosely packed between metal electrodes - see Figure 1-C. Later he also developed a coherer consisting of six hard steel balls, similar to those used in bicycle wheels, touching each other in a glass tube - see Figure 1-D. The resistance would drop form 2000 ohms to 100 ohms when a 1.5 mm spark occurred at a distance of about ten yards. He noted that a tap or slight blow to the tube would restore it to its high resis-

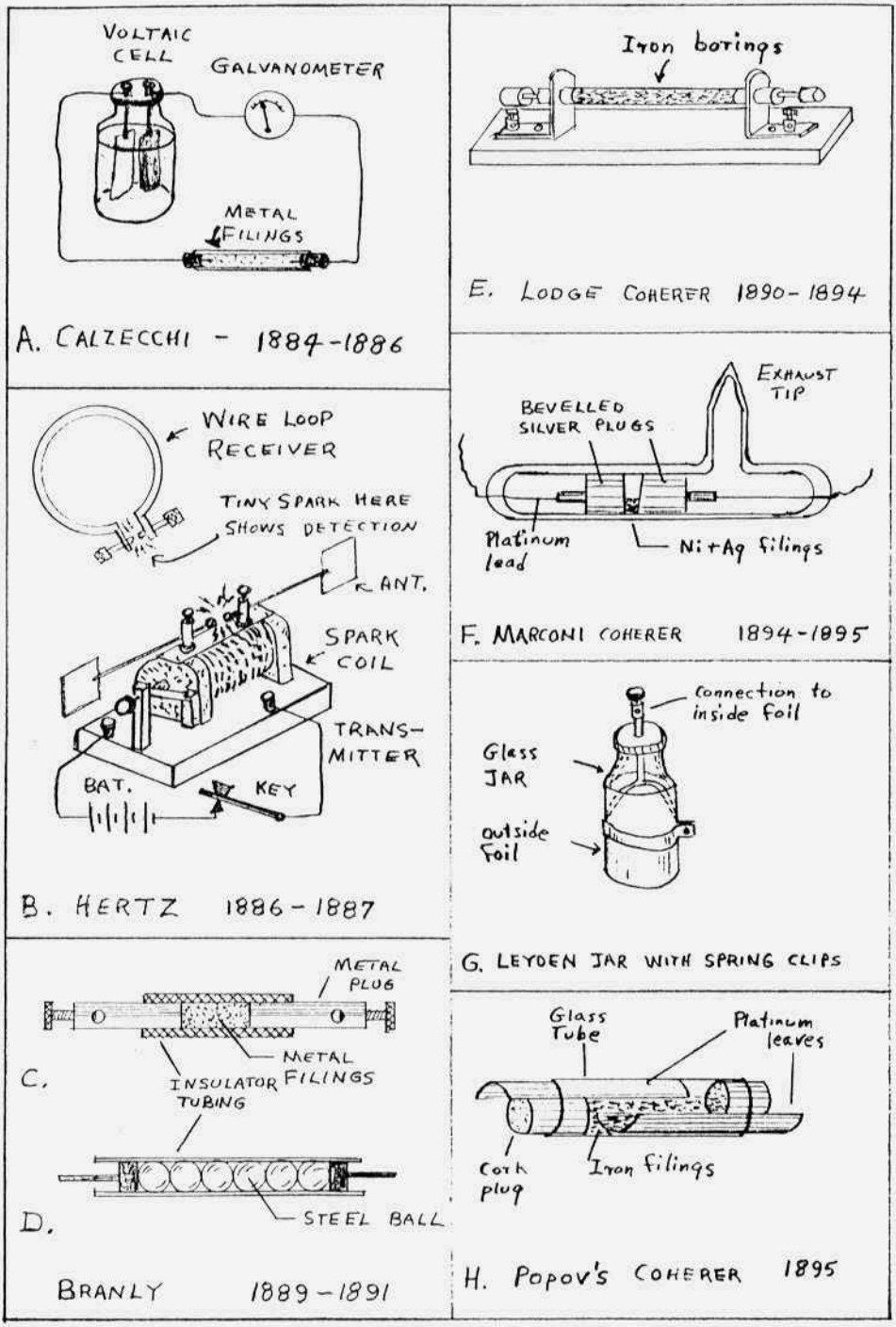

Figure 1. Some steps in the early history of wireless.

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tance state. Thus was born a new, more sensitive detector of electric waves. According to Fleming (1), only a few scientists at that time clearly recognized that it was the electric wave sent out by the spark that caused the coherer to respond.

A few years later, in 1894, Oliver J. Lodge gave a lecture in which he demonstrated an instrument which he named the 'coherer'. It consisted of a glass tube about 7 cm long, about 1 cm in diameter, loosely filled with coarse iron chips (lathe borings) and having a metal plug at each end - see Figure 1-E. Lodge noted that the device was somewhat tricky to adjust and its sensitivity and resistance would often abruptly change for no apparent reason. In 1897 he published a book entitled "Signalling Across Space Without Wires". While Lodge was able to transmit Morse code over a short distance with his equipment, he did not foresee its commercial application and thus it was left to the young Italian, Guglielmo Marconi, to 'invent' wireless telegraphy. However, to Lodge we must give credit for being the first to realize that the transmitter and receiver should be 'tuned' to the same frequency, a principal which he called 'syntony' (3) and we now term resonance.

The Marconi Coherer

Marconi was born April 25, 1874 in Bologna, Italy. He grew up at his father's estate, the Villa Griffone, near Bologna (4, 5). It was here he began his first wireless experiments. He had only a little formal training - some at a college in Florence when he was 14, then some at Leghorn Technical Institute where he pursued physics and chemistry. Later he audited Professor Righi's lectures at the University of Bologna. Here he learned about electromagnetic waves and decided to concentrate his work in that field. Righi allowed Marconi to use the equipment in his lab for his early research.

During some experiments at this father's estate, Marconi conceived the idea of using an elevated antenna and a solid ground connection. This markedly increased the distance he could transmit and led the way to ever larger and more massive antenna systems. Meanwhile, he worked on his coherer, gradually improving it to make it more sensitive, more reliable and more readily adjustable. In its final form (see Figure 1-F) it was about 5.5 cm long and 5 mm in diameter. He made the end plugs out of silver and coated them with a thin layer of mercury. These electrodes were given a slight bevel so that by rotating the tube on its axis, its sensitivity could be varied. Marconi experimented with various combinations of filings and discovered that a mixture consisting of 95% nickel and 5% silver gave the best results. He evacuated the tube and sealed it to keep out air and moisture. He also developed a magnetic tapper to restore the coherer after each signal was received. This was called the 'decoherer'. Incidentally, the Germans called the coherer a 'fritter' and the decoherer a 'klopfer'. Marconi's decoherer was similar to the mechanism of an electric bell with a brass ball as a hammer. It was arranged so as to strike the coherer from below to minimize 'packing' of the granules. His filings were much finer than those used by Lodge and he carefully screened them to eliminate the coarser particles.

Marconi arranged for his coherer to operate a sensitive relay which in turn controlled the tapper or decoherer, which took much more current than the coherer could safely handle. He discovered that the sparking at the contacts in the decoherer interfered by causing the coherer to switch 'ON' again after each tap. He cured this by adding choke coils (RF chokes) in the tapper wiring. Marconi filed for a patent on his coherer in June 1896 - just 100 years ago!

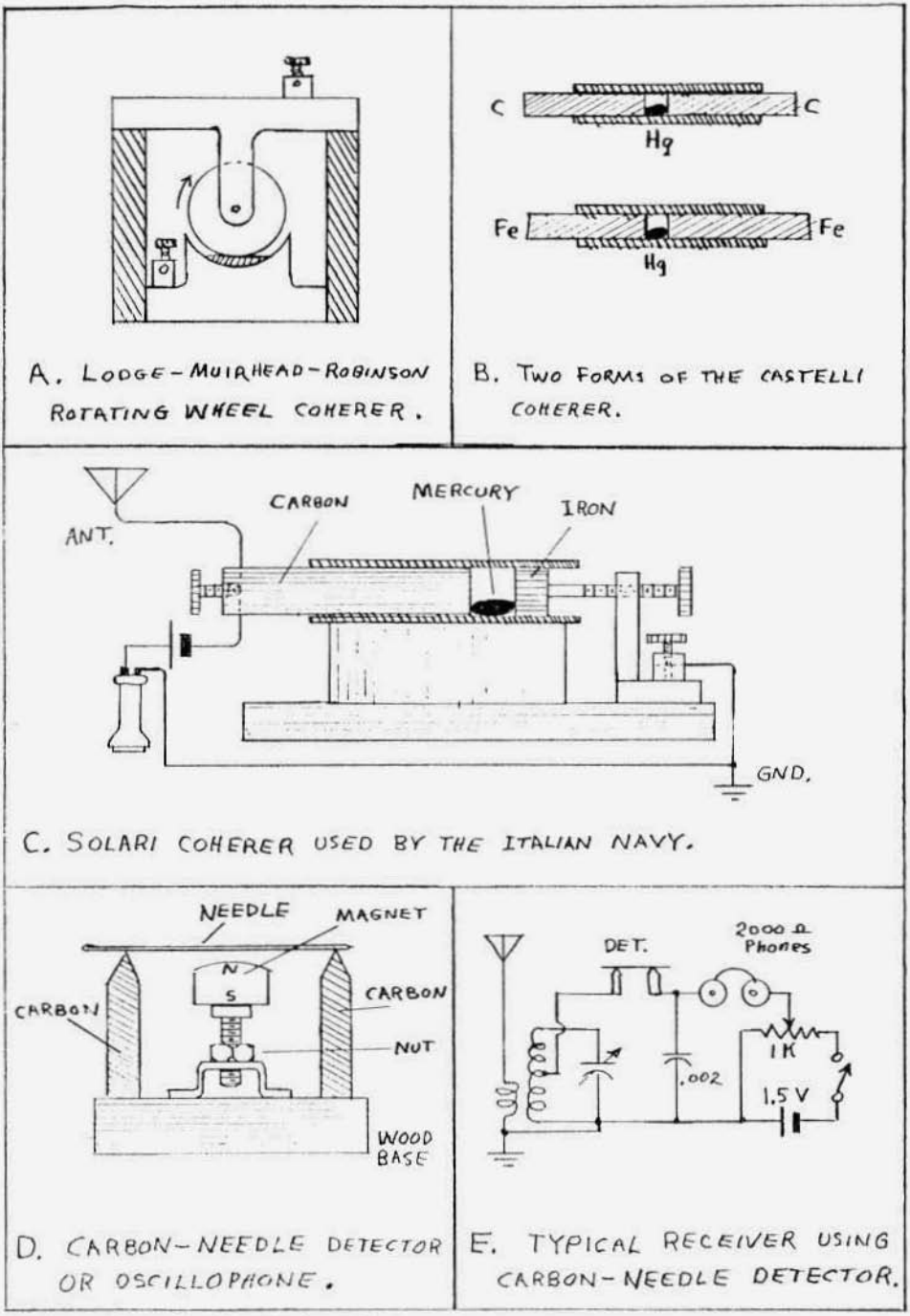

Figure 2. Several self-restoring coherers.

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Other Workers

After the coherer was discovered, many scientists began to study it in the hope of either improving it or getting around some patent. During this research, they discovered that way back in 1835, Munk af Rosenschold of Sweden mentioned that the conductivity of a mixture of filings of tin, carbon and other metals increased after a nearby Leyden jar was discharged. Note: A Leyden jar (see Fig. 1-G) is a condenser consisting of a glass jar with inner and outer coatings of tin foil. It received its name from the city in Holland where it was invented.

In 1856, S.A. Varley noticed that the resistance of a mass of metallic powders decreased during a lightning storm. He later invented a lightning arrester for use on telegraph lines, which was based on this phenomenon except that it used finely divided carbon.

A Russian professor, Count Popov, in 1896, made use of a coherer (see Figure 1-H) connected to an outdoor antenna and a ground wire to detect the approach of electrical storms. He also made use of an electric bell to tap and thereby reset the coherer after each flash was registered.

References 1 and 2 give details on more than three dozen coherers. Some of these are mind-boggling in their intricacy or cleverness. A study of this work can't help but imbue the reader with a feel for the excitement caused by the discovery of wireless communication. It must have been similar to the excitement caused by the discovery of gold in California or of oil in Oklahoma and Texas.

Self-Restoring Coherers

An interesting form of coherer is the 'wheel coherer' (see Figure 2-A) developed by Sir Oliver Lodge, Dr. Muirhead and Mr. Robertson, circa 1902. Here a small, slowly rotating wheel is arranged to barely touch the surface of a pool of mercury. The surface of the mercury is covered by a thin film of mineral oil. The electric signal punctures the thin film and a click is heard in the telephone receiver. Due to the rotation of the wheel, the detector is self-restoring and always ready for the next signal. A piece of felt is often arranged to wipe the wheel clean after it emerges from the pool of mercury. This coherer requires a bias of about 0.3 volt which is usually obtained from a potentiometer connected across a voltaic cell. It should be pointed out that coherers are essentially ON-OFF switches and thus not suitable for demodulating AM signals. But many metallic oxides; e.g. mercury, copper, zinc, do exhibit the properties of semiconductors and have been used as AM detectors. It's possible that some early self-restoring coherers may have actually been forerunners of the diode detector, (7).

A signalman in the Italian navy, P. Castelli, also developed a self-restoring 'coherer' about 1900. Figure 2-B shows two forms of his detector. The glass tube is about 3 mm ID and the electrodes are either iron or carbon. A single drop of clean mercury is placed between them. This detector also requires a bias voltage - usually provided by a single cell connected in series with a telephone receiver. In 1902, the Marquis Luigi Solari also of the Italian navy invented a similar coherer (see Figure 2-C) where one electrode was iron and the other carbon. It was used extensively by the Italian navy. This is the type of detector Marconi used in his 1901 transatlantic test (described later).

Loose Contact Detectors

Branly also discovered that two slightly oxidized steel or copper wires laid across each other with light pressure would act as a sensitive coherer. He observed the resistance to change from thousands of ohms to just a few ohms with sparks many yards distant. Maybe this is what led to the Massie Wireless Company's detector which

Marconi at Signal Hill, 1901.

they called the 'Oscillophone'. Two different forms are known. In one, two carbon V-shaped blocks support a steel needle (see Figure 2-D). An adjustable magnet under the needle varies the pressure that the needle exerts on the carbon. In another form, two single-edge razor blades support a carbon rod which may be a piece of pencil lead or the carbon anode from a small flashlight cell. The latter construction is said to have been used as an emergency 'foxhole' receiver by GI's during WW II. Since these were able to demodulate AM signals, they probably operated as diodes rather than as coherers.

Dr. J.C. Bose, a resident of Calcutta, filed for a patent on a 'coherer' September 30, 1901 which used galena elements. While he referred to it as a coherer, it seems likely that it really was a diode detector. He noted that his detector was sensitive, had quick response and didn't require tapping. It's possible that he came very close to being the inventor of the crystal detector.

Coherer Physics

Fleming (1) lists over a dozen names of those who have investigated the properties of coherers. Several of them proposed the theory that the particles are welded together to produce the 'ON' stage. In one experiment, iron filings were laid on a glass plate between two electrodes. After a nearby spark occurred, the filings adhered to each other to form chains from one electrode to the other. The loose or unconnected filings were then removed with a weak magnet exposing the cohered chains to view. Other researchers have pointed out that some materials such as carbon, arsenic, lead peroxide and a few others show an increase in resistance after the spark occurs. Furthermore, they say it's unlikely that carbon would be heated sufficiently to weld.

Research done at the Siemens Works (6) in Berlin during the 1930s and early 40s generally supports the theory that the metallic particles in a coherer are each enveloped by a thin film of tarnish (usually a monomolecular layer of oxygen having a thickness of 10 to 30 Å). It is this layer of tarnish that insulates the metallic particles from each other and gives the coherer its high resistance in the 'OFF' state. As the voltage across the coherer increases, it reaches a value sufficient to puncture the microthin tarnish film. The puncturing proceeds from particle to particle with great speed until the bridges are built from end to end. Then the resistance falls dramatically. At this point, the current rises and causes sufficient heating of the very minute sharp edges of these particles to melt them and cause fusing to occur. Now the resistance drops and the heating effect (due to I^2R) decreases just as suddenly so there is no runaway meltdown. Just the sharp edges of the tiny particles fuse. Only a light tap is required to break the threads (decohering

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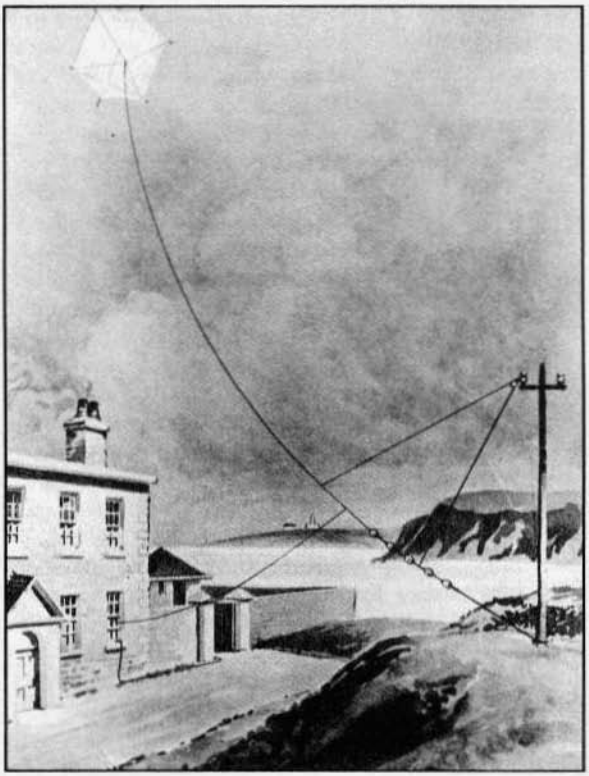

The kite antenna Marconi used at Signal Hill.

action). R. Holm (6) has suggested that the observed increase in resistance seen with certain materials after the influence of an electric spark might be explained by the concept that the bridges are annihilated by the electric shocks.

Modern Application

A modern application of the coherer was its use by a toy manufacturer in a radio-controlled toy bus. The hand-held transmitter used an induction coil and spark gap. The receiver employed a shock-mounted coherer, a relay and two motors - one for driving and one for steering. The control sequence was "Off-Left-Center-Right-Off". The range of reliable operation was about ten feet. One of the motors drove a 'whacker' to constantly reset the coherer.

Conclusion

On December 12, 1901, Marconi received the letter S, three dots, sent across the Atlantic Ocean from his high power station in Poldhu, England (4,5). His receiving station (see photo) was at Signal Hill, a high point on the coast of Newfoundland. The distance covered was about 2000 miles. His receiver used a Solari type coherer and the antenna was a long wire held about 400 feet aloft by means of a large kite (see photo). After Marconi heard the signal a few times, he handed the receiver to his friend Mr. Kemp who also heard it. Many people have expressed doubts about this story, but we must remember that there were no nearby transmitter, no trolley cars and no arc light to cause interference, very large antennas were involved and it's possible that good propagation conditions occurred that day. ER Next month part two.

Acknowledgements

The author wishes to thank Bruce Kelley, curator of the Antique Wireless Museum, Lucas Bazin, Ludwell Sibley and Robert Stapleford for their kind support.

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The Coherer Detector

Part 2. A Spark Transmitter and Coherer Receiver

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Synopsis

Part 1 (ER #86, June '96) reviewed the theory of the coherer radio wave detector and discussed several of the devices that saw application during the first decade of the twentieth century.

Introduction

When I was in seventh grade, I and my friend, Bob Richards, tried to build a spark transmitter and coherer receiver. His father had many nice tools so we were able to fashion a rather creditable contraption but, alas, the coherer refused to do its job. In retrospect, it probably did work but we tried to drive the bell-decoherer directly from the coherer without an intervening sensitive relay. Over the years I've thought that someday I should try once more. Then in 1996 it occurred to me that on the 100th anniversary of Marconi's improved coherer, it was time to try again. This time I met with success and the following story tells how it was done.

The Spark Transmitter (Photo 1)

The spark transmitter is very simple and similar to what a beginning ham might have used before WW I. It produces a train of highly damped oscillations which if connected to an antenna would cause severe radio interference over a very broad band of frequencies. Therefore you are cautioned to avoid connecting this transmitter to an antenna and to limit your experiments as much as possible.

The circuit is shown in Figure 1. Since the spark coil draws about 2 amps average primary current, No. 6 dry cells are used. D size flashlight cells just won't handle the load. The induction coil is an old Model T Ford ignition coil. These still turn up occasionally at flea markets and may be available from some automotive supply houses. To simplify mounting, the Ford coil was cemented onto a piece of thin wood.

I used an antique 1915 MESCO (Manhattan Electric Supply Co.) spark gap having 1/2" zinc electrodes. Zinc was said to produce a smoother sounding signal but for this application copper or iron will do just fine. I set my gap to a spacing of 2mm. Electrodes of this size and spacing require about 8 kv for sparking to occur. You can use a homebrew gap made of No. 14 wire. In this case, the spacing should be about 1/4" for the same breakdown voltage.

The Leyden Jar

You'll need a condenser that can handle this high voltage. A 500 pF ceramic TV high-voltage filter condenser will do but these were not available in the early wireless days so wouldn't be authentic. The early experimenters often made condensers using old photographic glass plates measuring 5 x 7 inches with alternating sheets of tin foil for electrodes. I chose to use a Leyden jar made as follows: I selected a glass jar with smooth sides - mine measured 2.9" in diameter and 6" high. The electrodes were made of ordinary kitchen aluminum foil. The foil for the inside cylinder was installed first. It was cut oversize so it would cover the entire 360° of the inside wall. I sprayed Duro All-Purpose spray adhesive on the inside wall

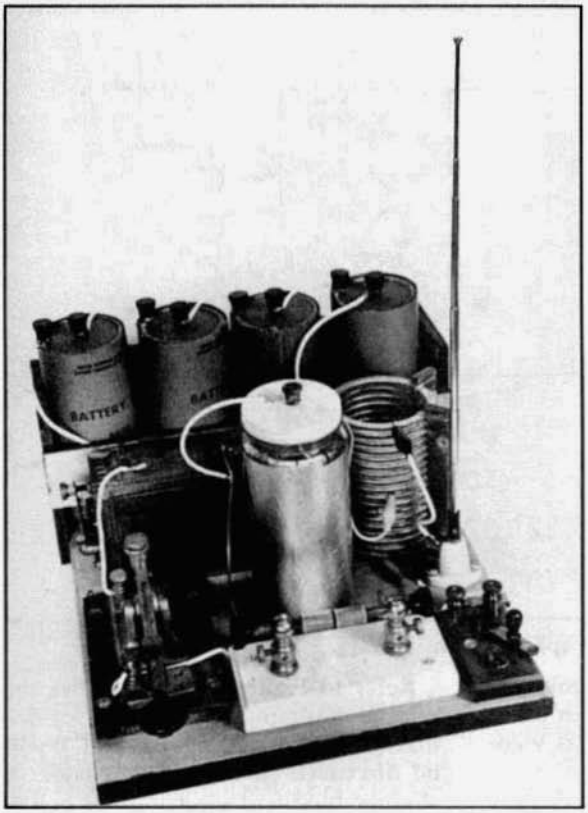

Photo 1. The spark transmitter. Ford coil is behind the key.

of the jar. Then the inner electrode was wound into a cylinder of about 1-1/2" diameter and carefully lowered into the jar. An 8" piece of 1/2" dowel rod was used to push the foil into place so that it formed a smooth coating on the inside glass surface.

The outside foil was cut to size (allow for a slight overlap), sprayed with adhesive and wrapped around the outside wall of the jar. Connections to the foils were made with insulated 7 x 30 stranded wire. I removed two inches of insulation and fanned out the strands. These strands were held against the inner (or outer) foil by cementing a two inch square of foil over the strands. The inner wire is soldered to a lug which is secured by the screw holding the binding post on the jar lid. The outer wire is anchored to the jar by means of a piece of No. 22 bus wire wrapped around the constriction near the top of the jar. My jar measured 450 pF.

The Coil

The coil, L1, is a Johnson 232-626 inductor edgewise wound with 1/4" copper strip. These come equipped with feet for mounting in a horizontal position. To conserve space, these feet were removed and the coil was mounted vertically by means of three angle brackets attached to the insulator strips. Connections to the coil were made using alligator clips.

The antenna is a telescoping affair removed from a Japanese transistor radio. A banana plug was screwed onto the base end and this plugs into a jack mounted in a Birnback 866J standoff insulator.

Key

Select a key with large contacts that will handle the fairly heavy primary current. I had an old military surplus key with 1/2" contacts and it does a good job and also looks antique.

Assembly

The transmitter components are assembled on a piece of 5/8 inch plywood measuring 11-1/4 by 12-1/4 inches. Two 11-1/2 inch runners of 1/2 by 3/4 inch wood are screwed to the bottom side so that some of the wiring can be concealed there. At the rear is a semi-open compartment that holds the four No. 6 dry cells. The wood members are glued together using contact cement. The raw edges of the plywood are painted with brown enamel. The other wood surfaces are stained and then finished with

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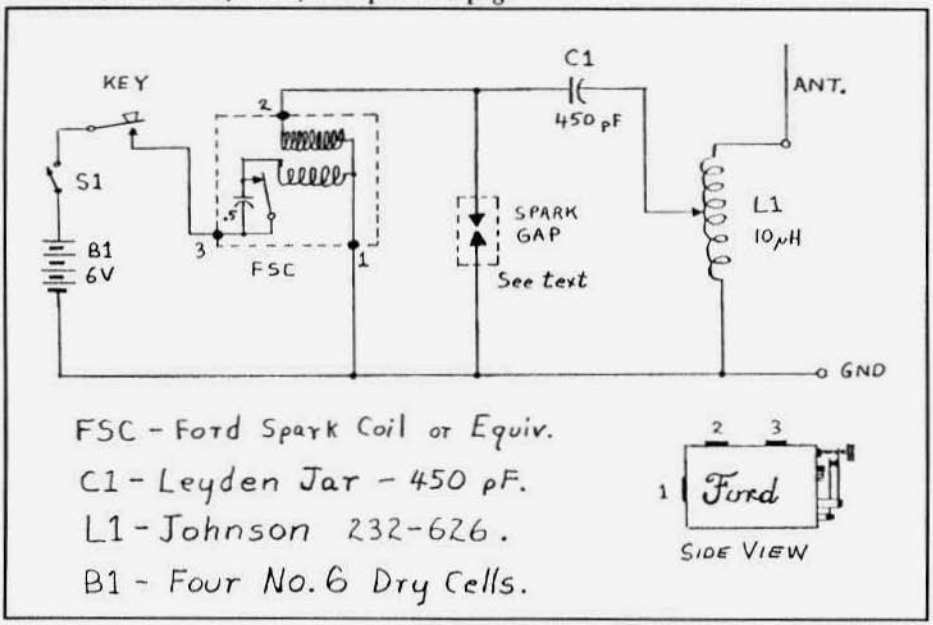

Figure 1. Wiring diagram of the spark transmitter.

two coats of clear, semi-gloss polyurethane. The Leyden jar is held in place with contact cement - two coats were used to ensure a strong bond.

Testing the Transmitter

Close S1 and depress the key. The Ford coil should buzz (vibrator working) and there should be a blue spark at the spark gap. If you have an ammeter, you can check the primary current. It will probably be about two amps. You may have to adjust the spacing of the vibrator contacts. You will probably be causing some interference on your wife's radio so keep testing to a minimum. Set the transmitter aside and start work on the receiver.

The Coherer Receiver

The coherer receiver is shown in photo 2. It is built in a manner similar to the transmitter using a piece of 5/8 inch plywood measuring 10-1/2 inches wide by 8.62 deep. The runners underneath are 7.75 inches long. They permit running most of the wiring below out of sight. The wood was finished to match the transmitter.

Refer to Figure 2 which shows the wiring diagram. That strange device marked FC is the filings coherer. It will be discussed in more detail later. A slightly modified electric door bell is used as the decoherer. When the signal from the transmitter acts upon the coherer, its resistance decreases and current from B1 flows through relay RY. The purpose of RFC1 is to prevent the relay circuit from shunting RF away from the coherer, which would impair its sensitivity. When relay RY closes, current from B1+B2 causes the bell to ring. The bell has been modified and has an extra hammer which is arranged to tap the coherer and thus decoherer the filings. Two items, RFC2 and C1, have been added to the circuit to prevent the sparking at the bell's vibrator contacts from turning the coherer 'ON' again. NOTE: The RF chokes are epoxied to the underside of the baseboard. They must have low resistance.

A close-up view of the coherer-decoherer is shown in Figure 3. You will note that an extra hammer has been

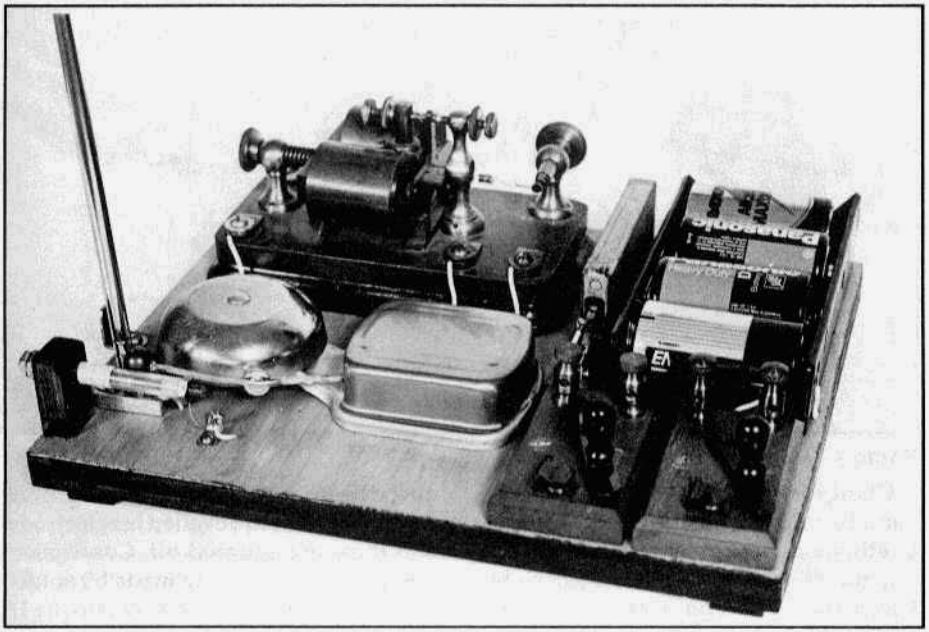

Photo 2. The coherer receiver.

added, whose purpose is to tap the body of the coherer and thus effect decohering. The arm is a piece of No. 14 bus wire. The hammer is a brass ball 7/16 inch in diameter. A No. 14 hole was drilled 1/8 inch deep into the ball and it was soldered to the bus wire.

The bell has two countersunk mounting holes hidden under the cover. Only the upper one at the base end is used and the flat head wood screw is not fully tightened. The bell can thus be rotated about this point to adjust how vigorous a tap the hammer gives to the coherer. A lever arm made of .06 inch brass is soldered to the underside of the arm that supports the bell. This lever projects slightly beyond the left edge of the baseboard and turns upward about 3/4 inch to facilitate manual adjustment of the position of the bell and the tapper. This brass arm is slotted and a screw permits locking the decoherer once the best position is determined. The base of the bell has a cutout for wires to pass through. A hole was drilled through the baseboard under this cutout and the bell wires pass through it. An old Western Electric condenser was used for C1.

Filings Preparation

Fleming (1) states that the magnetic metals nickel, iron and cobalt in the order named work better in a coherer than the nonmagnetic metals. He points out that in a metal-filings type coherer, it helps to add a small amount of some non-oxidizable or noble metal such as silver, gold or platinum. Marconi found that a mixture of 95% nickel and 5% silver gave particularly good results. One of my hobbies is chemistry so I happened to have samples of nickel and silver on hand. If you can't find these, Stapleford (10) suggests using a nickel and a dime. A nickel is made from an alloy which is 75% copper and 25% nickel. The US dime had the same alloy clad onto a core of copper. I suspect that you could also use filings from a common nail if you first file off the galvanizing coat of zinc.

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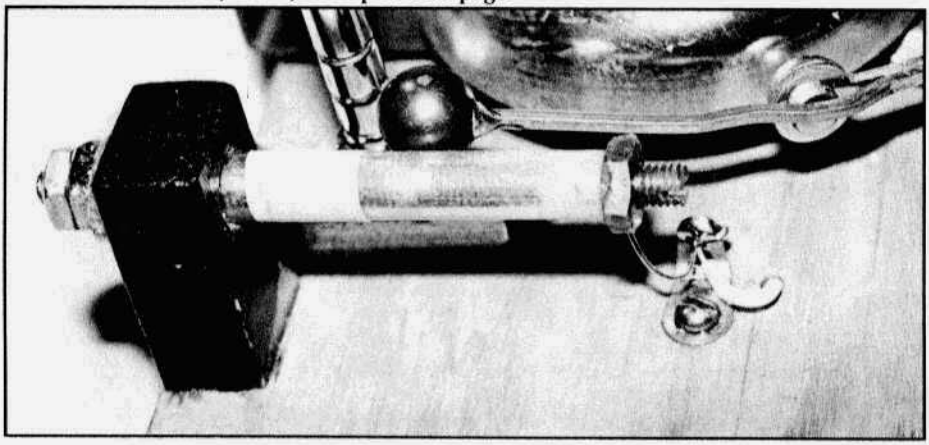


Photo 3. Close-up view of the coherer.

Clamp the host metal in a vise and use a fine file. Marconi sifted his filings to eliminate the coarser particles. I did not do this as mine looked all right. Catch the filings on a piece of clean, white paper. Only a small quantity is needed. Add a tiny amount of the silver filings. I put my filings in a small plastic box (about one inch cube) and shook it to mix the filings. They are now ready to use.

The Coherer

During the following discussion, it will help to refer to Figure 3. The body (T) of the coherer is a piece of plastic tubing 2-3/16 inches long with an ID of approximately .185 inch. For this I used the cylinder of a Stylex 1.00 cc hypodermic needle. Discard the needle and the plunger. The volume calibration marks on the barrel can be removed with ethyl alcohol. Cut off the needle end but don't remove the 'ears' (E) at the finger-grip end. Drill a No. 33 hole (H) about 1 inch from the left end, which can be used if it's ever necessary to add or remove filings. When not in use, this hole is covered with a small piece of masking tape.

The electrodes (S1, S2) were made from 10-32 threaded rods. You can use machine screws with the heads cut off. The ends of these electrodes which contact the filings are filed or ground smooth. Marconi bevelled his electrodes but these are squared off. Connections to these electrodes are made by soldering No. 24 bus wires (W1, W2) to the 10-32 nuts (N1, N2) which will later be cemented to each end of the main tube (T). Nut (N) is used to lock S1 after final adjustment.

Apply Duco cement to the body (T) at the end which fits into post (P). Slide T into P with H facing up. Let cement set. Insert screw S2 into nut N2 and tube T and advance it far enough so that the gap area will fall near the center of the exposed area of the tube as depicted in Figure 3. Apply cement to N2, T and S2 to lock this electrode permanently in place.

Now add the previously prepared filings to the tube. We want just enough to fill 3/4 of the space between S1 and S2 when they are about 2 mm apart. To do this, tilt the receiver 90° so that the filings can be dropped or poured into the open end near E. Pour in what you think will be enough, insert electrode S1 and set the receiver down level. Check to see if the filling is sufficient at the 2 mm spacing. If not, either add or remove filings as necessary. Now add N1 and cement it to the ears E taking care to not to get cement on S1 so that it

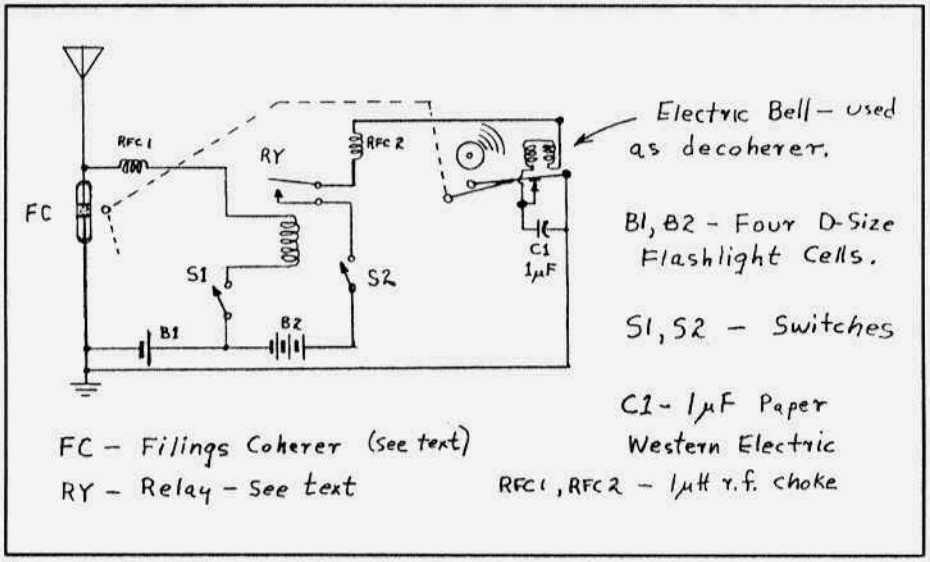


Figure 2. Circuit diagram of the coherer wireless receiver.

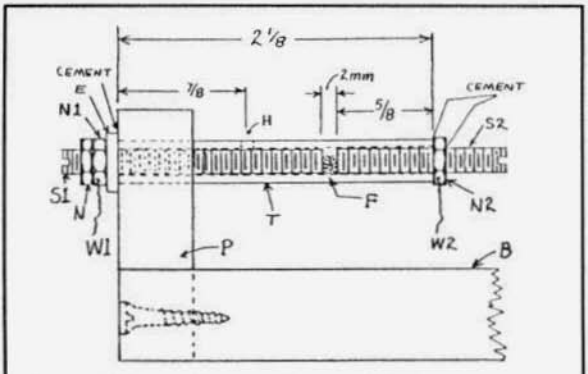
can be adjusted later if necessary. Temporarily tighten lock nut N after the cement has set.

The receiver antenna is a telescoping whip removed from a transistor radio. It screws into a small aluminum block just behind the coherer. Wire W1 connects to a solder lug attached to this block. Another wire from the other end of this same block passes through the baseboard to RFC1 and thence to the relay. Wire W2 connects to a solder lug on the baseboard just below the right end of the coherer. From here, a wire passes through the baseboard to the ground bus.

Testing the Coherer

I will relate the tests I made. Your results will depend on your coherer and your relay. My relay has a 150 ohm winding and closes with 7.7 mA and opens at 7.5 mA. I connected a 0-15 mA meter in series with the relay during the following tests. Place the transmitter near the receiver. Turn on S1 on the transmitter and S1 on the receiver. Depress the key momentarily. The current through the relay should increase - my meter showed 8.8 mA and the relay closed. Now close S2. The bell should ring once or twice and the current should fall to a lower value. My current dropped to 3 mA, on average and could be made to fall to 1 mA by tapping the coherer with a pencil. You may have to adjust your coherer and/or the position of the bell decoherer to make your receiver function properly. The bell should ring once or twice for a dot and ring longer when a dash is sent. If you've been busy with your pocket calculator, you've observed that the 'ON' resistance of the coherer is quite low - on the order of 15 ohms. If you check it with an ohmmeter you will probably see a higher value - perhaps 75 to 100 ohms. Coherers are tricky devices and may give widely variable results. You'll need a little patience - but remember - many, many life saving messages were received in the early years of wireless using a coherer as the detector. Incidentally, Marconi said that a metal filings type coherer should not carry more than 1 mA and he used a 1000 ohm relay. My relay was selected because it was available and had the proper antique appearance. If you find a relay that looks

continued next page



B -- Base of receiver, 5/8" plywood
E -- Ears on end of T, see text
F -- Coherer filings, see text
H -- Hole, No. 33 drill
N -- 10-32 locknut
N1,N2 -- 10-32 nuts with wires W1,W2 attached
P -- wood pillar, ½" x 3/4" x 1 3/4"
S1,S2 -- 10-32 threaded rods
T -- Plastic tube, see text
W1,W2 -- No. 24 bus wires

Figure 3. Contructional details of the filings coherer.

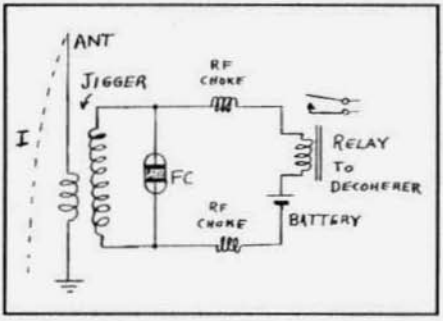


Figure 4. Marconi's jigger converted the antenna current to a voltage.

good but has insufficient resistance, it can be rewound with finer wire (1). This will allow more turns and hence greater sensitivity.

(1)Voltage Change Nomograph for Electromagnet Coils, Guy Buckner, W5VGK, QST, pg. 54, March 1959.

DX and the Jigger

I confined my experiments to the basement. If you decide to take your wireless station out to the county park for some 'DX' work, you'll need an assistant and a 'jigger' to help you. Marconi discovered that he could increase his range if he employed an antenna and a good ground connection. But Slaby of Germany pointed out that the vertical antenna produces a current at its base end whereas the coherer wants to see a voltage. To overcome this problem, Marconi used an RF transformer. The primary winding consisting of perhaps 50 turns of No. 22 wire was connected to the antenna and ground as shown in Figure 4. The secondary might have 320 turns of No. 46 wire. The transformer changes the antenna current to a voltage which is applied to the coherer. Marconi called the transformer a 'jigger' since it "poured the antenna signal into the coherer".

Conclusion

Although the coherer is less sensitive and less stable than the various detectors which followed, it did see extensive use in the early days of wireless communication. In February 1900, a German liner, the Kaiser Wilhelm, using a Marconi spark transmitter and coherer receiver, was able to contact a lighthouse 50 miles distant. During the next few years, numerous ships and lighthouses were equipped with similar outfits. Many lives were saved when sinking ships sent out the old time distress signal - CQD. Here in America, we interpreted this as "Come Quick, Distress" but Baker (7) says this is based phonetically on "Seek You, Distress". And again, Baker tells us that the letters 'SOS' don't stand for anything in particular (e.g. Save Our Ship) but were selected for reasons of ease of sending

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and being distinctive - easy to recognize. Many small ships had only one wireless operator and his relief man often didn't know the code but he was trained to recognize SOS.

The coherer, in addition to a lack of sensitivity, had another shortcoming - it was slow - its maximum speed being about 10 WPM. It was replaced, circa 1905, by the Marconi magnetic detector which gave a four-fold speed increase. But that's another story! ER

NOTE: References were given at end of part 1.

The Termite Talker from page 34

plifier and the triode connected 6AQ5 driver of the original Termite Talker modulator circuit. A meter salvaged from an Elmac AF 67 allows measurement of plate voltage, plate current, grid current and modulator current. The antenna changeover relay is built into the rig and is actuated by the push-to talk switch of the microphone. It might be of interest to other homebrewers that a small power transformer with a center-tapped 250 volt secondary works very well as a substitute for a single plate to push pull grids AF driver transformer.

The companion receiver (Termite Inhaler?) is built in the Termite Talker tradition. The front and side panels are masonite and the bottom plate is particle board. The circuitry is contained by three termite proof aluminum chassis. The power supply is mounted in breadboard fashion onto the particle board base plate. The RF chassis holds a 6BH6 RF amplifier and a 6BE6 converter. The 455 kHzs IF chassis utilizes two 6SG7 amplifiers and a 6H6 detector-AVC-ANL. The selectivity is fixed, but an external Q-multiplier can be plugged in if required. The audio chassis has a 6AU6 AF voltage amplifier followed by a 6AQ5 power amplifier. A large S-meter borrowed from a Hallicrafters S-76 graces the front panel which is painted to match the transmitter.

This station has been in use for several months and performs well. The transmitter was first put on the air on Thanksgiving day 1995, where it was one of an almost incredible 60 check-ins at KØOJ's second annual 80 meter AM Thanksgiving Day Bash. ER

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at which the frequency tunes up or down.

The External VFO's display uses LEDs to indicate the frequency in 100s of kHz, 10s of kHz, 1s of kHz, and 100s of Hz. The band is determined by either looking at the setting of the SB-104's bandswitch, or by reading the entire frequency directly from the SB-104's display.

Technical Information

The SB-645 uses an encoder wheel that is placed between the two parts of a U-shaped opto-isolator to vary the VFO's frequency. Each time the wheel interrupts the opto-isolator's light beam, the frequency changes 100 Hz. This stepping rate is more than acceptable when you operate SSB. In CW, it takes a little longer to get used to hearing the beat note change in 100 Hz steps, but is still quite acceptable. If you need smaller steps, you can always use the RIT function. Many modern-day transceivers do the same thing.

The External VFO uses 41 ICs and 15 transistors. It also contains its own regulated power supply for excellent frequency stability.

Closing Comments

Although the design was essentially finished, rumor had it that the product never went any farther because marketing was afraid of products that were so advanced for their time.

This completes a look at the SB-645 External VFO. Next month we will take a look at the HD-1781 Rotator. ER

The Coherer Detector

Part 3. Some devices that may act as either coherers or semiconductors

by Bob Dennison, W2HBE
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Westmont, NJ 08108

Introduction

Part 1 mentioned that some of the early coherers involving mercury were self-restoring and may have been precursors of the crystal detectors. My theory is that under certain conditions, the oxide layer on mercury can be punctured by an electric signal (coherer action) while under certain other conditions, the barrier layer may behave as a semiconductor. Furthermore, it seems likely that Lodge's crossed-wires or 'loose-contact' detector may have involved the same basic mechanism. This article will discuss experiments with two of these devices.

A Wheel Coherer

A wheel coherer was built to allow further investigation of this device - see photo 1. I found a small metal disc about one inch in diameter and attached it to a hub that would fit an 1/8 inch shaft. The motor is a Haydon timing motor with internal gearing to produce four RPM. Anything from two to five RPM should be suitable. A switch was provided to turn the motor on or off. The wheel dips slightly into a pool of mercury held in a plastic cup one inch in diameter and one-half inch deep. A wire encircles the bottom inside circumference of the cup to make electrical contact with the mercury. This wire is held in place by several small drops of epoxy.

The mercury cup is epoxied to a brass lever arm. At the left end, this arm is attached to a hexagonal aluminum post by two 4-40 screws. The rear end of this post is tapped for a 6-32 screw which then holds the arm assembly to the face plate of a 4 X 4 X 2 inch mini-box. This screw is left slightly loose in order that the position of the mercury cup can be adjusted so that the wheel just makes contact with the mercury.

A 3/4 inch long spring pulls the lever arm upward against a stop provided by a brass 6-32 screw. This screw permits adjustment of the penetration of the wheel into the mercury. A phosphor-bronze wire is arranged to bear against the hub of the disc to insure that it is constantly grounded.

The surface of the mercury is covered by a thin film of oil. Lodge specified mineral oil. My mineral oil was rather heavy and I got better results using thin watch oil. I suspect that ordinary household oil (3 in 1 or sewing machine oil) would do just as well. If you get too much oil on the mercury, the excess can be removed by touching the surface with a piece of absorbent paper towel.

To test the wheel coherer, I built the simple receiver shown in photo 2 with circuitry as shown in figure 1. Potentiometer R1 permits varying the bias on the detector. Most articles say that the bias should be .1-.3 volts. My detector worked best with about .45 volts.

Initial tests were made by setting the spark transmitter (see part 2) alongside the receiver. After an hour of experimentation, I still had heard no signal in the headphones. Perhaps the sounds of the Ford coil vibrator and the arc at the spark gap conspired to drown out any sound in the headphones. Now I knew how those kids must feel when they

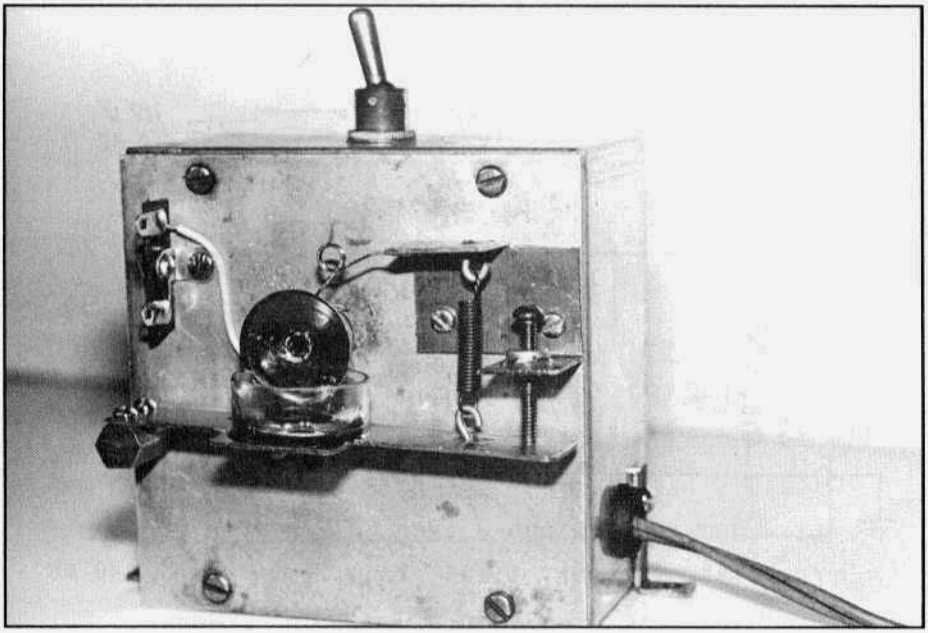

Photo 1. A wheel coherer.

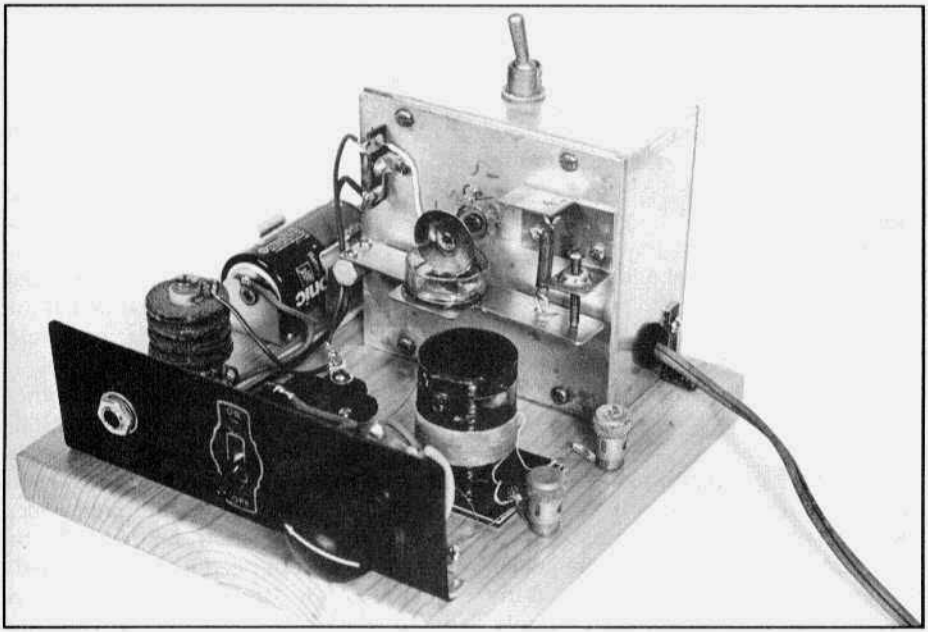

Photo 2. Complete wheel coherer receiver.

build their first receiver and it doesn't work. The next morning I had an idea. I hooked an RF signal generator to the ANT-GND posts and started adjusting the wheel. Suddenly, I heard the 400 Hz tone modulation! It would come and go

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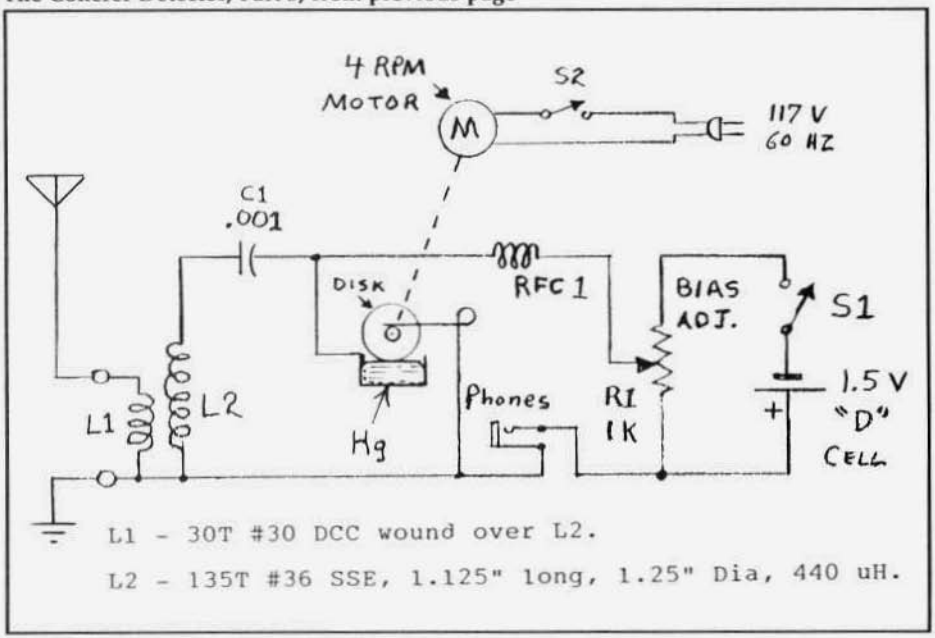

Figure 1. Wiring diagram of the wheel-coherer receiver.

because my wheel had some eccentricity. But, there was no doubt about it - the detector was less a coherer than it was a diode detector! Next, I connected it to an outside antenna and heard radio station WCAU - a 50 KW BC station only five miles away. Back in Lodge's time, there were no AM stations so this discovery had to wait many years. In fact, AM broadcasting began long after the wheel coherer was abandoned so I may be the first person to discover this phenomenon. When I turned off the motor to stop the wheel, reception would usually continue for a few seconds, then cease.

Phillips (2) gives the history of the development of the wheel coherer. It didn't arrive full-blown in one sweep of inspiration but went through the usual trial and error process common to invention. At first, Lodge, et al, simply used a pointed iron wire dipping into the oil-covered mercury pool. Each time a signal was detected, the wire had to be lifted to restore the detector. Next, they attached the pointed wire to a vibrating tuning fork so that there was recurring restoration. Finally, the wheel type device was conceived.

Phillips (2) points out that several early workers mentioned that, for best results, the wheel should have a positive bias. This also attests to the fact that the detector is acting as a semiconductor diode with the wheel acting as the anode, hence conduction is enhanced with a positive bias on the wheel. If the device was a coherer, polarity would not matter.

All of this may explain why the other mercury type detectors work. The Italian navy detector probably relied on a thin film of mercury oxide to make it a semiconductor. These primitive devices were noted for their tendency to be unstable and in need of constant readjustment. The life of the early wireless men must have been one of constant frustration. It is not too surprising then that inventors would seek and soon discover more stable semiconductors using crystal-line solids to replace the finicky mercury devices. Starting in 1902,

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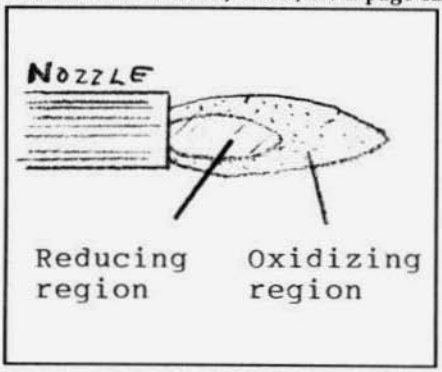

Figure 3. Location of oxidizing region of flame.

G.W. Packard (14) began a systematic study of various minerals and discovered many important semiconductors such as iron pyrites, galena, chalcopyrite, silicon and the perikon detector which consisted of a piece of zincite (iron pyrite) pressing against the surface of a piece of chalcopyrite. Later, H.C. Dunwoody discovered that carborundum (SiC) also was a good detector and he applied for a patent in March 1906.

Many an early wireless operator, on finding a particularly sensitive crystal detector, would carry it with him from one tour of duty to the next, rather than rely on what he might find in the ship's wireless room.

An Improved Fox-Hole Radio

In part 1 I mentioned Branly's work with loose-contact coherers using oxidized wires. His work led to various discoveries from the Oscillaphone to the fox-hole receiver. I built one of the latter as shown in Figure 2. Various combinations of materials for the anode and cathode were tested with the following results:

ANODE	CATHODE	RESULTS
Carbon rod	Razor blade	generally poor
Carbon rod	Oxidized nail	slightly better
Carbon rod	Oxidized copper wire	Good
Copper wire	Oxidized copper wire	Also good

Apparently, the iron oxide layer is not very strong and is easily damaged or cut through when pressed against the anode. But the cuprous oxide (Cu_2O) cathode gave better results. When tuned to the local radio station, WCAU, I got the following headphone currents:

DETECTOR	BIAS	uA
Cu_2O	Zero	35
Cu_2O	1.5V	80
1N34A	Zero	150

The cuprous oxide layer was formed as follows: A six-inch piece of clean No. 14 bare copper wire was clamped in a vise with about 2-1/2 inches extending away from the jaws. This wire was heated in the oxidizing portion of the flame (see Figure 3) for two or three minutes. Let the wire cool and then examine it. It should have a dark, brownish-black color. If you measure the wire diameter before and after heat treatment, one-half the difference is the thickness of the oxide layer. I found this to be about 1/4 mil. Since the oxide layer is very thin, it is easily damaged.

If you decide to build such a receiver (see photo 3) a few notes may be helpful. The tuning condenser is a standard 365 uuF variable. The inductor, L1, is a single-layer solenoid of 72 turns of No. 30 DCC wire. Length and diameter are each 1-1/4 inches. The coil was tapped every five turns from 10 to 45 turns. I got best results with the antenna connected to the 20 turn tap and the detector connected to the 30th turn. In order to tune the entire broadcast band, the coil should have an inductance of 250 uH. My coil needed a ferrite core to achieve this inductance. I used a piece of ferrite 3/8 inch in diameter and 1-5/8 inch long. It is cemented to the inside wall of the coil.

When broadcasting started - about 1921 - crystal sets became very popular. Nearly 400 companies are known to have produced such sets. Today, Radio Shack still sells a crystal set in kit form. Today's germanium crystal diodes are considerably more efficient than the early galena-catswhisker types.

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Why AM from page 23

3. Fred Johnson in Electric Radio, number 58, February, 1994, pg. 12 & 13.
4. The American Radio Relay League, The ARRL Handbook For Radio Amateurs, 17th edition 1993, pg. 18-1, The American Radio Relay League, Newington, CT 06011, USA.
5. Emphasis in the original.
6. Emphasis in the original.
7. Harold Ennes, Television Broadcasting. Equipment, Systems, and Operating Fundamentals. First edition, Howard W., Sams & CO., Inc. The Bobbs-Merrill Co., Inc., Indianapolis-Kansas City-New York.
8. Stan Prentiss High Definition Television, 2nd edition, TAB Books Division of McGraw-Hill, Inc., Blue Ridge Summit, PA.
9. Any ham who has aligned an old Viking Pacemaker, or any other phasing type SSB rig can quickly grasp the principles of QAM.

The Coherer Detector, Part 3 from page 14

Professor Branly died in 1940 at the age of 95. He lived to see radio progress from his coherer (1890) to such wondrous things as vacuum tubes, AM and FM broadcasting, television, facsimile, radar, radio altimeters and direction finders and, of course, most precious to us, amateur radio. The next fifty years brought us still greater marvels - loran, color TV, video tape recording, satellite systems, cellular phones, paging, hi-definition TV, cable TV, digital logic, transistors, integrated circuits, and much more. It has been a remarkable century of electronic development and it all started with the coherer about 100 years ago. ER

NOTE: References were given at end of part 1.

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start, capacitor run.
Maximum Cable Resistance: Terminals 1 and 2, 8 ohms. Terminals 3-8, 2 ohms.
Rotation Time : 45-60 seconds with 60 Hz input.
Brake: Positive, electrically-operated wedge. 75 segments spaced 4.8 degrees apart.
Rotator Size: 8" maximum diameter x 13.5" high, (20 cm x 34 cm).
Maximum Antenna Mast Size: 2-1/16" OD (52 mm).
Mounting Hardware: Stainless steel and plated steel clamping plate.
Weight: 23.4 lbs. (10.6 kg)

The manual recommends inside tower mounting and it is desirable to use a thrust bearing on the mast at the top of the tower. Such an arrangement helps protect the rotator from side bending forces and you can use an antenna with up to 15 square feet of wind loading. Other methods described are outside tower mounting and top mast mounting. These latter two methods will handle antennas with up to 7.5 square feet of wind loading.

It is also recommended that you use shims between the mast and rotator mounting surfaces to help reduce bearing and motor wear by keeping the weight balanced.

Closing Comments

The rotator got as far as the proofbuild stage, but was canceled because we could not get a good enough price break on parts from Telex/Hygain.

This completes a look at the HD-1781 Rotator. Next month we will take a look at the GR-1133 aircraft scanner. ER

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